# Problems and Prospects to Screen and Breed for Tolerance to Soil Salinity: A Case Study with Chickpea

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**Abstract**

*It is imperative that tolerance of crop species to soil salinity be improved because salinization of agricultural soils will continue to occur. Recognizing the limits to which salts can be tolerated in a given crop species, such as chickpea, and the variability that is available in the germplasm, it should be possible to screen a large number of genotypes for this trait, both in pots and in the field. This should allow identification of material that can immediately be used as cultivars or as parents in a breeding program. This paper suggests how heterogeneous soil salinity under natural conditions can be used in field screening of genotypes for salinity tolerance. It proposes methods for advancing breeding material and for testing the end product in a program to breed chickpea cultivars with increased salinity tolerance; the approach may also be applicable to pigeonpea.*

## Introduction

The papers presented at this workshop point to the increasing threat to crop productivity from salinization of agricultural soils. Lands that previously were productive have had to be abandoned for cultivation due to this menace, which is associated with the introduction of irrigation in many countries in recent years (Abrol and Bhumbla 1971; Mohammed 1976, cited in Wyn Jones 1981; Ponnamperuma 1977). To return these lands to cultivation and to retard or prevent loss of further land to salinity, two options are available: (1) reclamation of salt-affected soils, and (2) crop selection or genetic improvement within a crop species for salt tolerance.

The traditional approach of reclaiming saline and sodic soils, though difficult in terms of time and money required, has been very effective and widely recommended (USDA 1973). It has produced encouraging results in India, Israel, Pakistan, the United States, and many other countries. Although it is possible to restore the soil's full agricultural potential when other factors do not limit productivity, reclamation is often constrained by various geographical problems. For example, in parts of California, USA, and Haryana, India, it has not been possible to adequately drain saline subsoil water.

The second option of living with the salts seems to have become increasingly necessary. Earlier, selection of crop species for cultivation on saline soils was considered not very useful or promising (Hilgard 1906, cited in USDA 1973). That it is practicable to select for salt tolerance was indicated in work with tomato (Lyon 1941); this possibility was later demonstrated with the selection of a highly salt-tolerant barley cultivar that could be grown with irrigation using sea water (Epstein and Norlyn 1977).

The role of tolerance to soil salinity in increasing and stabilizing crop productivity should not be overplayed, however. It is unrealistic to expect resistance to salinity in crop plants in the same way that resistance to biotic stresses of diseases and pests has been achieved. One has to accept that there are limits to the tolerance of excess salts in the soil by different crop species. Within a given crop species, although

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there might be a large genetic diversity for various traits, there may only be a narrow range of genotypic differences in tolerance to salts.

## The Salinity Problem

Salinity occurs in heterogeneous patches (Abrol and Bhumbla 1971; Chandra 1980), and the ionic composition of salts varies from place to place. For example, the saline-alkaline soils in Haryana, Punjab, Rajasthan, and Uttar Pradesh have a predominance of sodium; saline soils in southern parts of India have chlorides and sulfates of sodium with large quantities of $CaCO_3$, and saline soils of West Bengal have a predominance of magnesium (Abrol and Bhumbla 1971). This variability in ionic composition of salts in saline environments seriously constrains selection and breeding of genotypes with a wider adaptability across locations. Further, the reaction of species or cultivars for tolerance to salts is not a definite feature of a cultivar since it changes with atmospheric factors, such as humidity (Hoffman and Jobes 1978) or temperature.

Because of the heterogeneous occurrence of salinity in the field, it is not considered possible to study responses to soil salinity under field conditions (Chandra 1980). Also, since chickpea is sensitive to salinity, it has been suggested that it may not be possible to make use of yield-based criteria in this crop (Chandra 1980). But as our primary concern is productivity in saline environments, it is necessary that only yield-based criteria are used, rather than indirect indices of yield performance.

## Poor Plant Stands

The occurrence of poor plant stands is a common feature in saline fields, and this inevitably reduces yield. Differences between crop species in germination under saline environments are well known (Mehrotra and Gangawar 1964; USDA 1973), and variability within crop species has been noted for pigeonpea and chickpea in artificially salinized soil. Seeds of genotypes better able to germinate in saline environments would be very useful in improving plant stands and thereby contributing to increased and stable yields. Genotypic differences in tolerance of different ionic species are also of practical importance, in view of the differences in the types of salts in saline soils and the modifying influences of other accompanying ions, such as calcium.

## Tolerance to Salinity

### Criteria for Selection

#### Visual Criteria

In saline environments, chickpea exhibits development of distinct symptoms, such as the appearance of anthocyanin pigments on the foliage in the desi cultivars and the characteristic yellowing of the foliage in the kabuli types. In a moderately saline environment, which does not cause plant mortality or a severe reduction in growth, relative genotypic differences can be detected under field conditions by observation of symptoms. Such differences are not so visible in pigeonpea, however.

#### Relative Biomass and Yield Reduction

Two different weight-based criteria have been described to determine genotypic differences in salt tolerance (Chandra 1980):

1. the level of soil salinity that would bring about a 50% reduction in shoot weight or seed yield; and
2. relative decline in biomass or yield with increasing levels of soil salinity (slope of the response curve).

### Screening Methods

#### Field Method

As pointed out earlier, heterogeneity of soil salinity is a discouraging factor in developing field screening methods; therefore, pot methods, using artificially salinized soils, are recommended (Chandra 1980). At ICRISAT we are trying to use the natural occurrence of heterogeneous soil salinity to our advantage. The procedure followed is to grow each chickpea genotype in a long row across a moderately saline field, passing through the heterogeneous patches of salinity (Fig. 1). A test line in a row is flanked by a tolerant and a susceptible control. The genotypic differences in salinity can be scored in two different ways: visually, and by relative decline in plant biomass and yield.

1. **Visual scoring.** Genotypes are scored on a 1-9 scale for severity of foliar symptoms due to soil salinity, in relation to tolerant and susceptible controls. The scale used is as follows:

1 = No symptoms visible
3 = Symptoms visible on older leaves, but plant apparently normal
5 = Symptoms visible on all leaves, but plants can produce pods
7 = Severe symptoms (burning and scorching)
9 = Susceptible (plants dead)


**Figure 1.** A field method of screening chickpea for genotypic differences in tolerance to soil salinity.

**Table 1.** Genotypic variation in chickpea of intercepts (potential dry matter), slopes (tolerance to increasing levels of salinity), and EC (electrical conductivity) levels that bring about a 50% reduction in dry matter (n = 32).

| Genotypic variation | Intercepts | Slopes | EC for a 50% reduction in total dry matter |
|---|---|---|---|
| Minimum | 0.38 | -0.17 | 1.19 |
| Maximum | 0.99 | -0.05 | 2.95 |
| Mean | 0.60 | -0.10 | 1.68 |
| SE ± | 0.019 | 0.003 | 0.059 |
| Variance | 0.011 | 0.0004 | 0.110 |
| Standard deviation | 0.107 | 0.020 | 0.331 |
| CV (%) | 17.9 | 20.7 | 19.7 |

In studies to date, genotypes exhibit distinct differences in reaction to salinity, and genotypes with a greater degree of tolerance in the field (e.g., L 550) also prove to be tolerant in greenhouse tests.

2. **Relative decline in plant biomass and yield.** The relative decline in biomass and yield of genotypes is also determined by recording dry matter and yield at a number of positions along the line where growth differs. Soil samples are taken from these areas to determine the salinity (electrical conductivity, EC) level. Yield and biomass are then regressed against salinity level to determine:

a. relative differences in slopes in dry matter and yield with increasing levels of salinity (EC) among genotypes; and
b. differences among genotypes for the level of salinity that would bring about a 50% reduction in yield.

This method is very laborious, however, and may not be practical on a large scale.

#### Greenhouse Method

The above regression approach was tested in pots in a greenhouse, using graded levels of soil salinity and maintaining the soil moisture around field capacity. The crop was harvested 40 days after sowing, and the biomass was regressed against the graded levels of

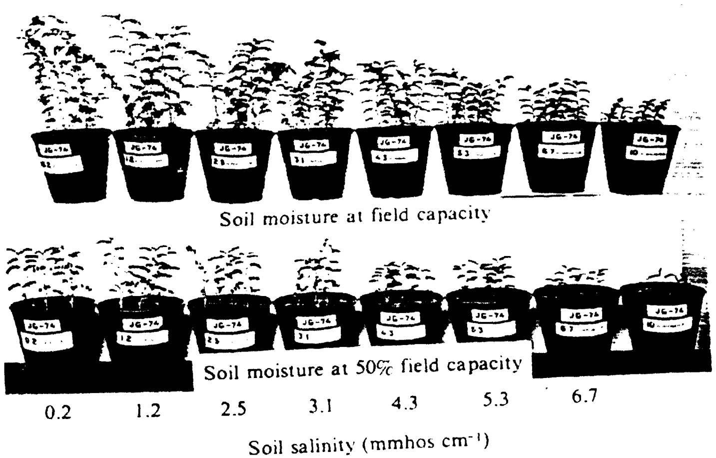


**Figure 2. Effect of interaction between soil moisture and salinity on the growth of chickpea (cv JG 74).**

salinity. Genotypic differences in tolerance to salinity appear to exist (Table 1), and a wide range of germplasm should be examined to determine the extent of such differences.

## Interaction of Soil Salinity with Moisture

The osmotic effects of dissolved salts in soil solution, which contribute to physiological drought, are well recognized (Wyn Jones 1981). In the pot experiments conducted at ICRISAT Center to study the responses of chickpea to graded levels of salinity, we observed that the decline in dry matter in chickpea with increasing levels of soil salinity was more steep in well-watered conditions (pots maintained around field capacity) than in water-deficit conditions (pots maintained at around 50% of the field capacity) (Fig. 2). Studies in the field exhibited a similar response. This indicates that genotypic differences may be easier to detect when soil water conditions are kept at an optimum for plant growth.

## Breeding for Tolerance to Salinity

Once considerable genotypic variability is detected by the screening methods discussed, a breeding program for salt tolerance becomes feasible. Genotypes with greater salt tolerance than the commonly grown cultivars can be selected as parents. The above screening techniques, however, would not be suitable for selecting promising material in a segregating population.

Generally, genotypic differences are greatly na rowed down at very high levels of salinity an hence, such levels cannot be used to screen segreg ing populations in a breeding program. The atten

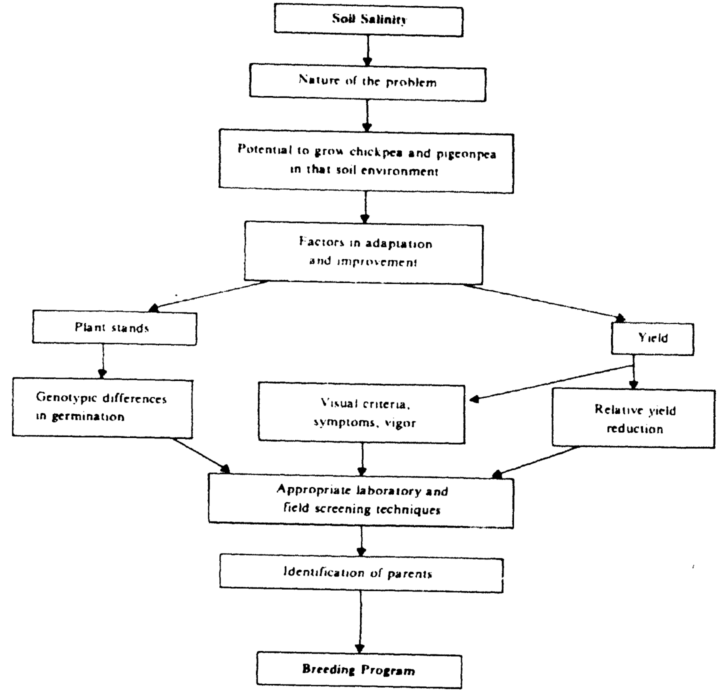


**Figure 3. A schematic diagram of steps required for a breeding program on tolerance to soil salinity.**

should be to arrive at an optimum level of soil salinity at which expression of genotypic variation is maximum. This level can be decided upon for a given soil type and climatic condition by growing a few contrasting genotypes at graded levels of soil salinity.

The chosen level of salinity can then be created in artificially salinized microplots in the field, or in pots, in which the segregating population can be grown. Selections and generation advancement can then be made on the basis of visual differences in relative growth and appearance of symptoms. The promising material could finally be tested more comprehensively at graded levels of soil salinity, in pots or in heterogeneous field conditions as described earlier.

An overall schematic approach is described in Figure 3. The approach may also be applicable to pigeonpea.

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